TECH ENGINEERING NEWS

JANUARY · 1942

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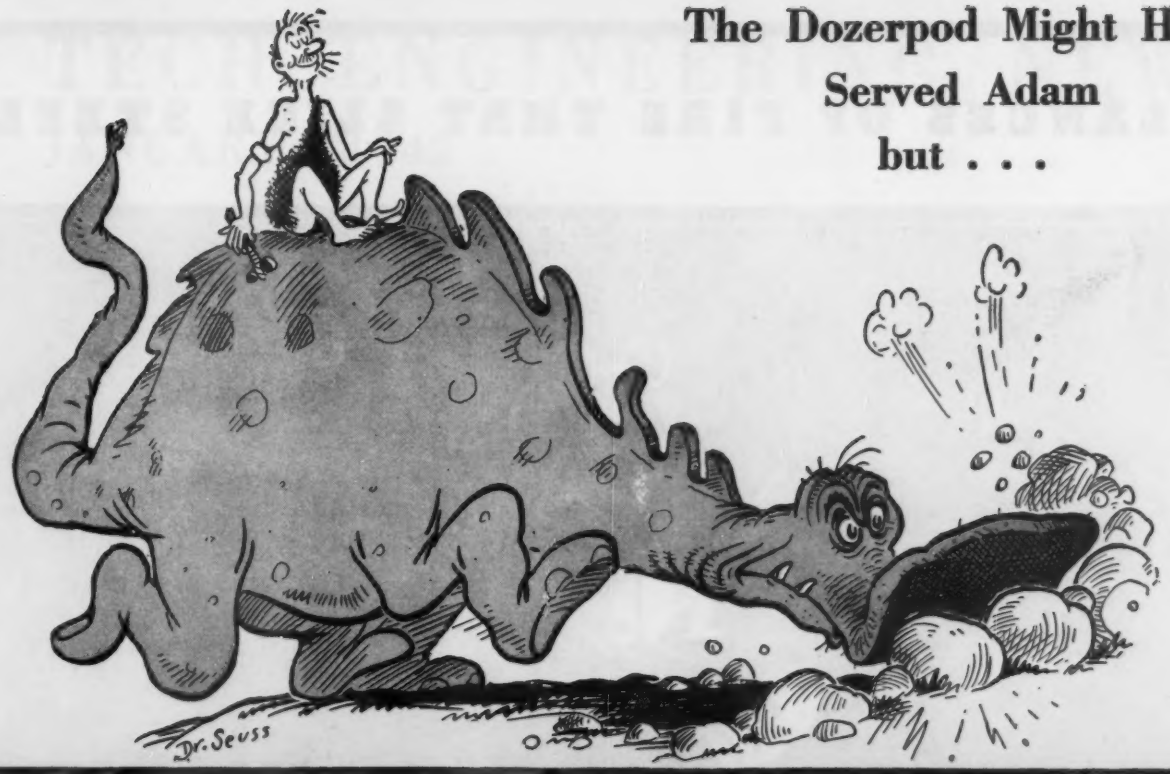

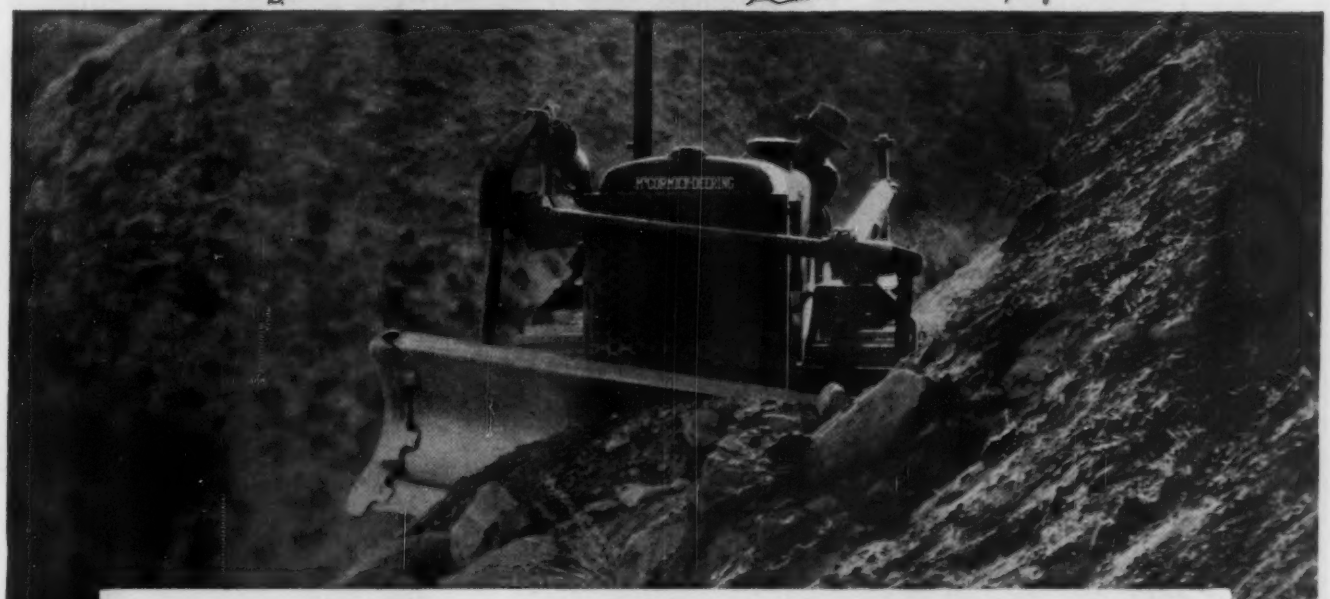

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TECH ENGINEERING NEWS

JANUARY · 1942

VOLUME XXII

NUMBER 8

OUR COVER THIS MONTH
A prize-winning construction shot by John Cutler, G.

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EXIT:

"Number Please!"

By VIRGIL EDWARD OTTO '43

HOW THE CHANGEOVER TO THE NEW CROSSBAR DIAL TELEPHONE SYSTEM IS ACCOMPLISHED

AT the present time, there are over a million telephones installed in Chicago, which take care of 4,700,000 calls per day. This represents a twofold increase since 1920. As in the case of other large cities, it was apparent in Chicago that manually operated switchboards could not continue indefinitely to adequately serve the local operating problems. It followed that the switching equipment needed to complete the necessary connections in telephone work would have to be mechanical in order to give efficient and speedy service. Several of the manually operated exchanges of the downtown area had already been converted to dial operation, and this service was found to be very successful. Since then, several sections of the residential areas in Chicago have been converted. The newest installation of dial equipment will serve Rogers Park, Chicago's north side residential district. This exchange contains five office units servicing 42,400 telephones. The total cost of the conversion project will run to about four million dollars, of which approximately three million will be spent for central office dial equipment. It is the purpose of this article to outline the installation procedure and to explain the general features of the latest type of dial telephone equipment known as Crossbar.

The first type of mechanical switching device was called step by step equipment; later, came the panel dial system; and since 1936 the Bell system has been installing still a later development, the crossbar dial system. The best arrangement for serving this large residential area with due consideration of interconnection with the metropolitan area and other Chicago offices is the crossbar dial system. The switching mechanism of this system is designed to provide flexible and economical trunking arrangements for large cities, plus the most up-to-date operating features, so it can easily handle areas where there is a high traffic rate. The new installation will be designed to work with the older types of equipment in the surrounding areas.

Crossbar is essentially a relay system, which in general contains no continuously moving parts. This avoids to a large extent the troubles of a mechanical type.

The system consists principally of crossbar switches, multi-contact relays, and the usual small relays similar to those generally employed in all telephone systems. The switching circuits are wired to the contacting springs of the switches, and the connections through the switches are made by pressing contacts together by means of simple electro-magnetic structures, instead of the moving brushes and associated fixed bank terminals of other systems.

The crossbar switch is a multiple relay structure with twenty vertical relay-like units, each unit having an operating or "holding" magnet and ten sets of contacts in a vertical row. The typical switch arrangement provides a rectangular field of contacts in twenty vertical and ten horizontal rows, or a total of two hundred sets of contacts, one set at each "crosspoint." These crosspoint contacts are operated independently of each other by a coördinated operation of the horizontal and vertical bars. The horizontal bars are controlled by the ten horizontal or "selecting" magnets, and the vertical bars by ten or twenty vertical or "holding" magnets, depending on whether it is of a one hundred or two hundred cross point capacity unit. Since the contacts are held in operation by the holding magnet alone, the selecting magnet is operated only momentarily, and is released as soon as the holding magnet is seized. So it follows, that after a selecting magnet is released, other connections may be established through the switch by the operation of other selecting and holding magnets. The main piece of equipment is the crossbar switch shown in Figure 1. These crossbar switches, which perform the major switching operations, are provided with twin contacts of precious metal (palladium) to reduce circuit failures due to corrosion and dirt.

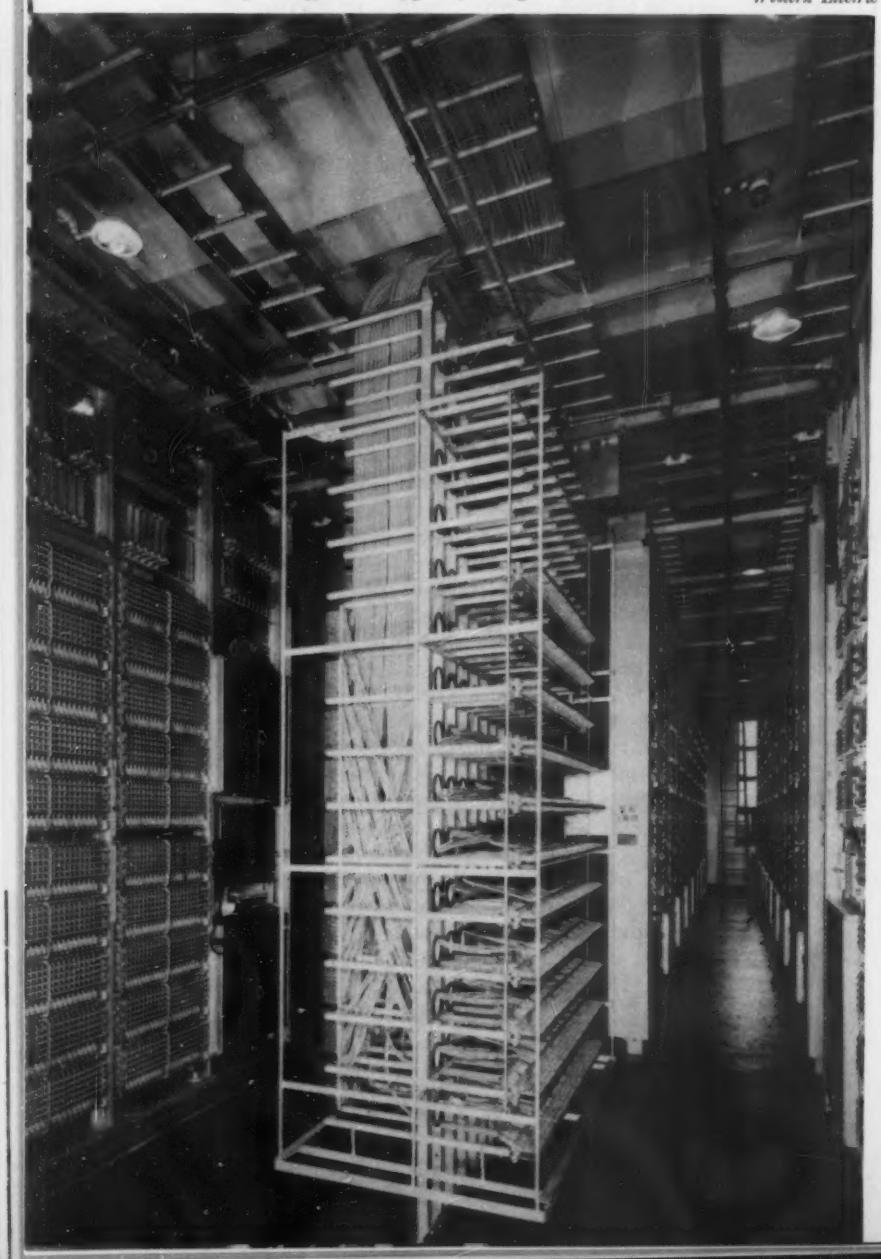
One of the most remarkable operations in the establishment of a call is performed through the terminating marker, one of the frames in the system. In dial systems, other than crossbar, a talking path is established step by step through the various portions of equipment right up to the selection of the called telephone number. If the called line is busy, considerable equipment is held up until the calling party disconnects. Instead of this procedure, the markers go around to the back door, so to speak, to find out whether the called subscriber's line is busy. If it is, the busy signal will be given immediately and little equipment will be tied up. If the called line is not busy, the missing steps in the talking path will be completed. It sounds like an impossible per-

formance but the Bell System engineers have developed this principle for improving the efficiency of various equipment parts.

This huge conversion to dial telephone operation in Rogers Park is scheduled to take fifty weeks. It directly involves three main groups of experienced telephone workers; namely, the Illinois Bell Telephone Company, the Western Electric Installation Department and the Western Electric Company, Inc., Manufacturing Department. It might be interesting to outline briefly the planning of an installation such as the Rogers Park Crossbar Exchange from the time it was first conceived, until the time of the final cutover from manual to dial operation. This requires very extensive studies on the part of the telephone company extending usually over a period of several years. These studies are carried on by highly specialized groups, as follows:

The Commercial Engineer, the Plant Extension or Fundamental Plans Engineer, the Traffic Engineer, the Equipment Engineer, the Building Engineer and the Outside Plant Engineer. It is the telephone company's job to keep a perpetual record of what the subscriber needs in telephone service. They keep close tab on the density of telephone traffic and determine from data whether or not the present equipment is sufficient for the traffic loads that will be encountered. In the Rogers Park area, crossbar dial central office units were decided upon to replace the present manually operated switchboards. It now becomes necessary to determine the number of frames of equipment that will be required in the new units. A portion of the equipment is tied up but momentarily, while other equipments are utilized for the whole duration of the conversion, so the engineers must work out with the aid of traffic capacity tables the amount of equipment required to handle the peak load and the housing facilities they must arrange for. The telephone company's equipment specification is now prepared. This places their equipment requirements on the manufacturer and supplier.

Distributing frame where connections are made for different type of telephone service *Western Electric*



All of the central office telephone exchange equipment for the new exchange is manufactured by or supplied through the Western Electric Company, Inc. When the manufacturers receive the engineering specification, their first job is to schedule the work involved in manufacturing and installing the new central office equipment. After a job is scheduled, one knows the specific days on which the manufacture of equipment will be completed, the shipping dates, and the day for the cutover of equipment. It is important to know these intervals so that sub-schedules can be made up for the individual manufacturing departments and the Western Electric Installation Department.

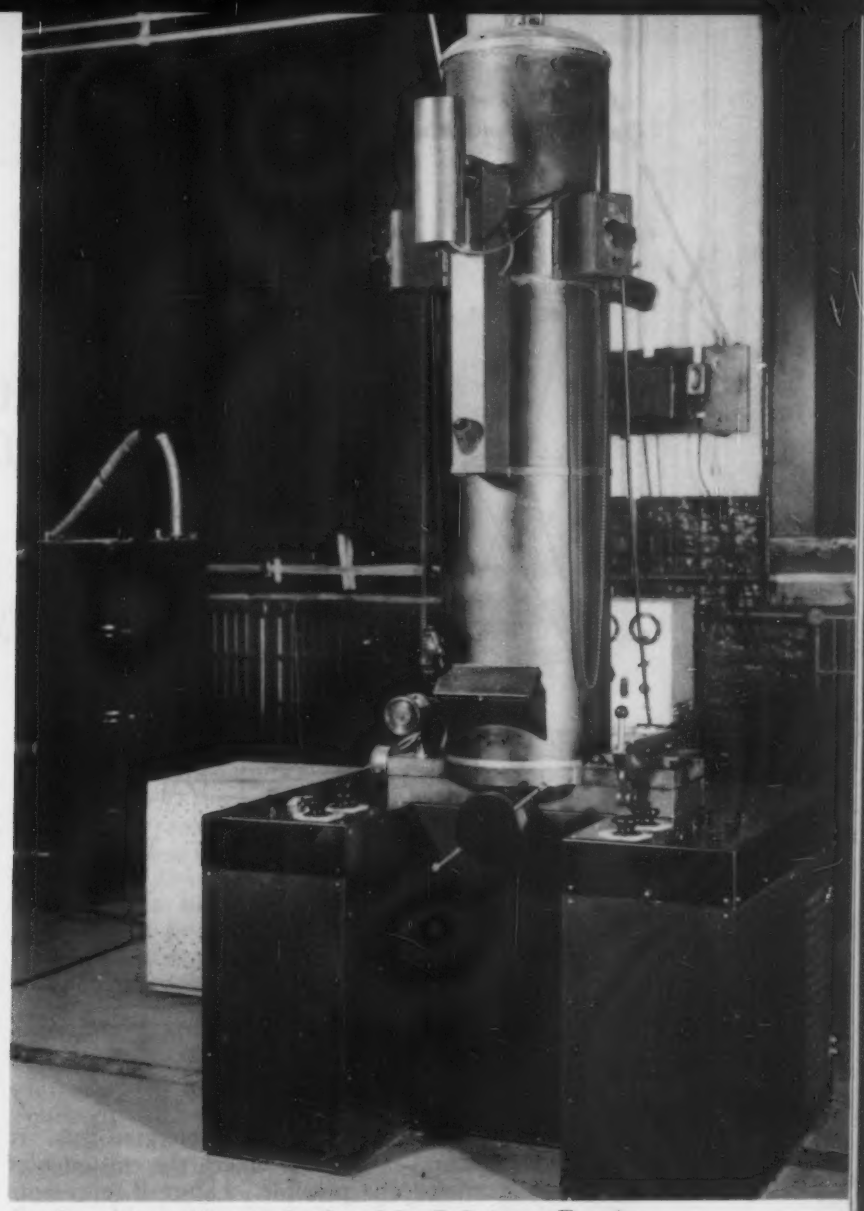
It is the responsibility of the equipment engineering department at the Western Electric Company, Inc., to transform the telephone company's requirements listed in their specifications, into manufacturing terms. It is always necessary to divide the entire order into individual specifications which cover the equipment, cabling, wiring and other installing details.

The entire job of installing the new equipment is done by an installing crew. An average of one hundred and fifty men are required to finish the job in the allotted fifty week schedule. While some of the more complicated equipment is still being manufactured by the shop, the heavy iron details and the superstructure are delivered to the premises and installed. The first job is to erect the superstructure, which will hold in position the equipment frames to be set in later. The superstructure is bolted to the ceiling inserts. With this arrangement, the equipped frames are held in position by the superstructure, and at the same time all of the weight is supported by the floor.

The next important job is to set the frames in place and bolt them to the superstructure. Rogers Park requires approximately seven hundred frames, which will make up the largest crossbar office to date. As some frames weigh as much as a ton, it is easy to realize why the work of placing and aligning will run over a period of eight weeks. Each frame is complete in every detail; the wiring terminated on terminal blocks, the equipment is verified and adjusted before leaving the Western Electric Company, Inc., plant. After the frames are installed, they must be interconnected by means of switchboard cable according to a definite plan.

While one group of installers is finishing the assembly work in the exchange, another group is starting on cabling. This part of the installing interval takes some twenty-four weeks. Sometimes, there are as many as three hundred wires in a single switchboard cable, and the installer has a definite sequence of colors to follow, known as a "color code," when he is connecting them to the terminal strips. By the use of this color code, identification of terminals is established.

An important part of installation technique is running cross connections or "jumpers" as they are called. This kind of wiring is done on the block relay frames and on the distributing frames. Such type of wiring serves as a flexible connection between two pieces of equipment, connections that can be changed quickly and easily, as when a subscriber moves or changes his type of telephone service. (*Continued on page 202*)



An electro magnifier as developed by R.C.A. *Electronics*

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ELECTRON MICROSCOPE GREATLY INCREASES POSSIBLE MAGNIFICATION IN MANY FIELDS

By GEORGE G. HARVEY

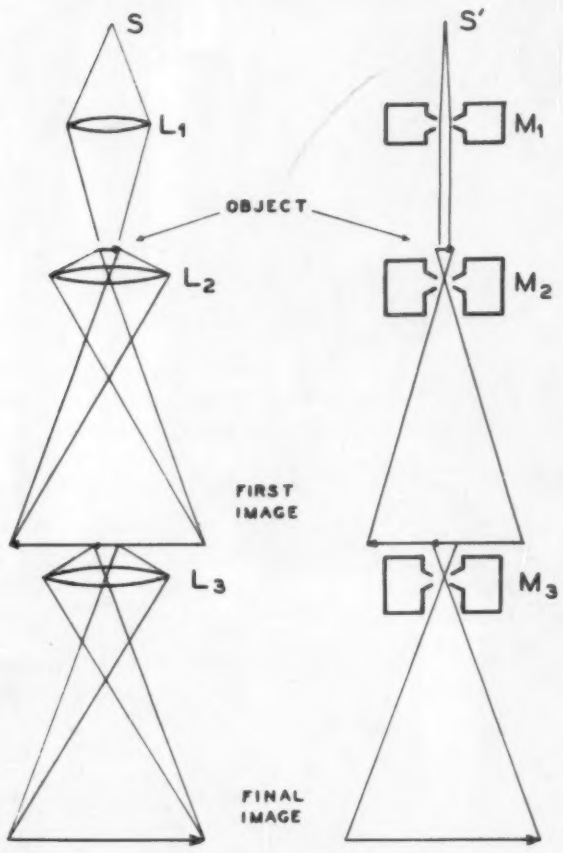
PROFESSOR, M.I.T. PHYSICS DEPARTMENT

IN the past few years considerable attention has been devoted to the development of the electron microscope. Some of the results obtained with this instrument are rather startling; perhaps the most spectacular is the smallness of the objects that may be examined and the fineness of detail that the electron microscope reveals.

Fundamentally, the electron microscope operates on the same principles that the ordinary light microscope does, the difference being that a beam of electrons is used instead of a light beam and magnetic (or electrostatic) fields instead of glass lenses. Figure 1 shows schematically the similarity of the two instruments, for the case of the magnetic electron microscope. The light source S in the optical microscope is replaced by the electron source S' in the electron microscope. This consists of a hot tungsten filament. The condensing lens L_1 is replaced by the magnetic lens M_1. This coil collimates the beam of electrons to "illuminate" the object. The magnetic lens M_2, the objective, forms an enlarged image of the object, just as does the optical objective L_2. A portion of this is further magnified, by the eyepiece or projection lens L_3 in the optical case and by the projection coil, M_3, in the case of the electron microscope. The final electron image can be viewed on a fluorescent screen, or photographed for permanent record.

Before describing the microscope in more detail, a word about electron lenses may not be out of place. The construction of optical lenses is made possible by reason of the fact that the path of a ray of light through a transparent medium is determined by the index of refraction of the medium. If the index of refraction changes from point to point the path of the light ray is curved, in general. Now a beam of electrons moving in an inhomogeneous magnetic field has many of the properties of a beam of light in a medium of variable refractive index. In particular, by suitably distributing the field, a divergent beam of electrons from a point source may be focussed, or imaged, at some other point.

Figure 1. Comparison of light and electron microscopes



That is, we can construct a magnetic electron lens. It is this fundamental fact which makes the existence of the electron microscope possible. Figure 2 represents schematically a cross section of a typical magnetic electron lens. It consists of a cylindrical coil winding A, surrounded by a soft iron case B. The purpose of the lens is to produce in the region C a highly concentrated axial magnetic field symmetrical about the arrow. Such a field affects a beam of electrons in much the same way as a converging lens affects a beam of light. In particular, if the field extends over a region which is short compared with the object and image distances, it acts like a thin lens of focal length $f = k\,V/I^2$ where V is the potential through which the electrons have been accelerated and I the current through the lens coil. k is a constant depending on the geometry of the coil. It is well to note that all electron lenses of this type are positive (converging).

The foregoing discussion has been concerned with the possibility of constructing an electron microscope. Questions of equal importance are: what are the advantages of such an instrument and to what are they due? To answer these questions we must consider the factors which influence the resolvng power of a microscope. In Figure 1 we have assumed that light travels in rays; that is, we have neglected its wave aspect. This is all right provided we are not dealing with objects whose size is comparable with the wavelength of the light used. If we wish to examine such small objects then we must take account of diffraction, and it is this which essentially limits the resolving power, and thus the useful magnification, of a microscope, even though all geometrical aberrations were eliminated. Without going into further detail we recall the Abbe formula for the limit of resolution of a lens: $\Delta = 0.61\,\lambda/n \sin\theta$. In this formula Δ is the distance between two points in object space such that the first minimum in the diffraction pattern of one of these points in image space coincides with the principal maximum in the pattern of the other. We arbitrarily define this distance Δ as the limit of resolution and, in practice, two points will not be distinguishable as separate if they are much closer together than Δ. This distance Δ is seen to depend on the wavelength λ of the light used, on n the index of refraction of the medium between the object and the objective, and on θ the semi-angle subtended at the object by the objective. To make Δ as small as possible we must obviously use short wavelengths and make $n \sin\theta$, the numerical aperture, as large as possible. Optical microscopes using oil immersion can have a numerical aperture as high as about 1.6 as a maximum. Thus, by using ultraviolet light it has been possible to get Δ down to something like 500–1000 angstroms. ($1A = 10^{-8}$ cm.)

Now let us consider the case of the electron microscope. According to the de Broglie relation, with a particle of momentum p there is associated a wavelength λ given by $\lambda = h/p$, where h is Planck's constant. Expressing this in practical units, for an electron which has been accelerated through a total potential difference of V volts, the wavelength λ (*Continued on page 200*)

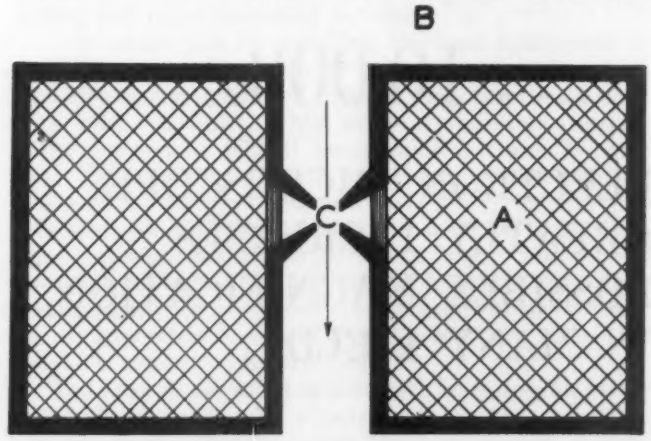
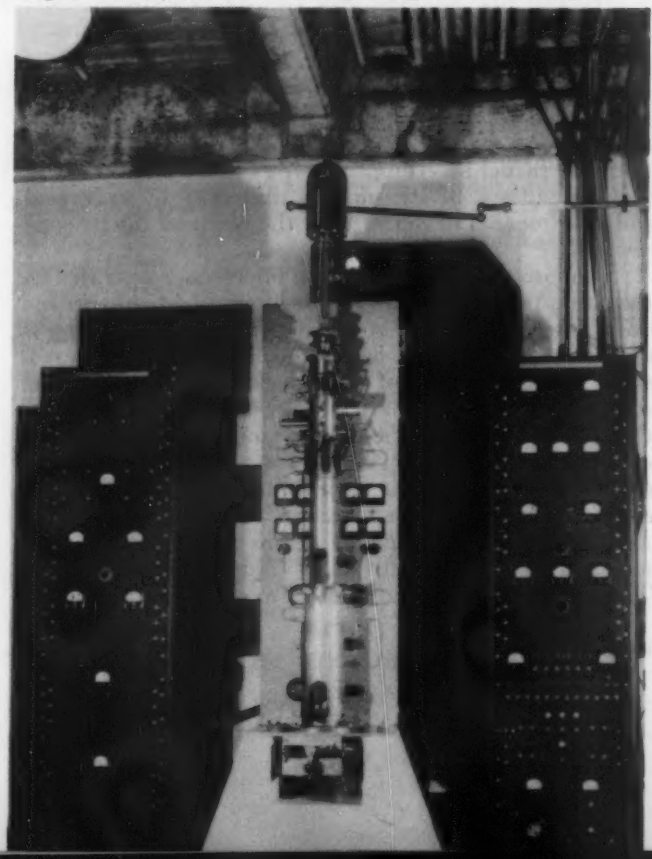


Figure 2. Cross-section of magnetic electron-lens

Figure 3. (a) General view of complete microscope



GEMS— AND BORT

THE AGE-LONG SYMBOL OF AFFECTION IS AN ENGINEERING NECESSITY

By MYRON EVERTS

PRESIDENT, NATIONAL RETAIL JEWELERS ASSOCIATION; GOVERNOR OF THE GEMOLOGICAL INSTITUTE OF AMERICA; PAST PRESIDENT, JEWELERS RESEARCH GROUP

PERHAPS some day diamonds will be manufactured in the laboratory just as most precious stones can be duplicated artificially today. Already many claims to successful diamond manufacturing have been advanced. However, the Gemological Institute of America, which was organized several years ago as a scientific and educational institute and also as an agent to arbitrate disputes concerning stones, has not approved any of these claims.

All of these manufactured stones to which the claim of diamond has been given have been of such small size and of such a type that they could not receive every scientific test. Some of the particles have been extremely hard, resembling the true diamond in this quality, but whether these have had the same degree of refraction of light has not been determined.

If the diamond is ever manufactured successfully, it is my opinion that this will not affect the price and value of Nature's own creation. Today there are thousands of synthetic rubies on the market but the ruby produced by Nature has lost nothing in value. The manufacture of some synthetic stones is an expensive process which in many instances has been abandoned because the cost has been prohibitive.

Should it now be possible to produce synthetic diamonds successfully Germany would not have had to resort to its recent drafting of gem diamonds of rare beauty to fill the role of the now scarce industrial "bort" needed to produce tanks, airplanes, guns and submarines.

According to reports filtering through to jewelers in this country, German officials are now commandeering gem diamonds from rings, clips and bracelets to take the place of the industrial diamonds kept out by the British blockade. It is the belief that some industrial diamonds from Brazil have run the blockade and reached Germany but that these have not been sufficient to set with diamond points the tools engaged in precision work.

A munitions factory without industrial diamonds would have to close up shop. Diamonds are as necessary as petroleum to a war-waging nation. The stone has a thousand industrial uses.

Because the diamond is the hardest substance known to man, receiving its name from the Greek word "adamant," it is the material used to drill, to carve, to saw other hard substances. Holding a place far in advance of all minerals, the diamond is 85 times as hard as the corundum — the ruby and sapphire — which occupies second position.

Machine parts of every type are turned by diamonds. Pistons can be trued on a lathe with a diamond-pointed tool to one ten-thousandth of an inch accuracy. Diamond-set tools turn out the bores of guns so cleanly that no polishing process need follow. Gold, silver, platinum, iron and tungsten can be drawn through diamond dies into wires of microscopic size. In an experiment which received wide attention, a platinum wire was silvercoated and this wire was extended through diamond dies until one ounce of platinum was long enough to stretch from Maine to Southern California.

Tungsten, one of the hardest metals known, can be shaped easily by the diamond. Tools equipped with diamond points cut through granite as readily as a dasher turns in an ice cream freezer. Half of the diamonds in the world are classed as commercial "bort" and put to such industrial uses. The best of these commercial diamonds are tough and full of knots, similar to the knots in wood.

While the mechanized world constantly is offering new tasks for the industrial diamond, the stone of gem quality continues to hold rank as the chief token of sentiment. To the jeweler this is the enthralling phase of the diamond industry.

A survey printed in *Harper's Bazaar* last May showed that of the 113,000 girls married every month in the United States, 110,000 of these receive diamond engagement rings. Only in America does this occur. In other lands through the ages precious gems have been reserved for royalty or for the ornamentation of war decorations. Americans own more diamonds than any other people. Considering this it seems appropriate that since the beginning of World War II the diamond market of the world has shifted from London to New York.

Probably because of the prevalence of diamonds, many people have the idea that vast quantities of the gems are mined each year. This is not true. In 1928, which was the peak year for diamond production, if every family in New York had decided to give the mother a one-carat diamond for a Christmas gift from the year's output of the mines, this would not have been possible. There were not (*Continued on page 207*)

TIME IS VICTORY

A GLANCE AT THAT TIME-SAVER, THE NOMOGRAPHIC CHART

By DOUGLAS P. ADAMS
INSTRUCTOR IN GRAPHICS AT M.I.T.

In searching for possible economies of time or money in an engineering process it is very natural to arrange operations of equal magnitude in the order of frequency of their repetition and to expect the greatest opportunities for ultimate savings among those which occur most often. Applications of this purely abstract and elementary principle have recently revolutionized certain assembly processes and provide repeated practical support for the postulate that the broad art of engineering is synonymous with the development and application of good method. Frequently engineering processes include several mechanical or routine operations which must be individually controlled, integrated, or ultimately interpreted through the use of mathematical formulas. Clearly those economies made in carrying through such repeated mathematical operations may with the lapse of time become as valuable assets as other more tangible ones which can be used but once. Hence we turn to graphical methods as a recognized means for time-saving in mathematics.

AN alignment[1] chart is a diagram which provides a graphical method for solving an equation for its nth variable when the values of the other $n-1$ variables have been specified. It contains several curves or sets of curves (the straight line being a special curve), one for each of the variables of the given equation. On a given curve or set of curves appear graduations corresponding to convenient values of that variable. The design of the chart is such that any set of values of the variables which satisfies the equation *lies along a straight line.* It is this property which gives these charts their great practical engineering value.

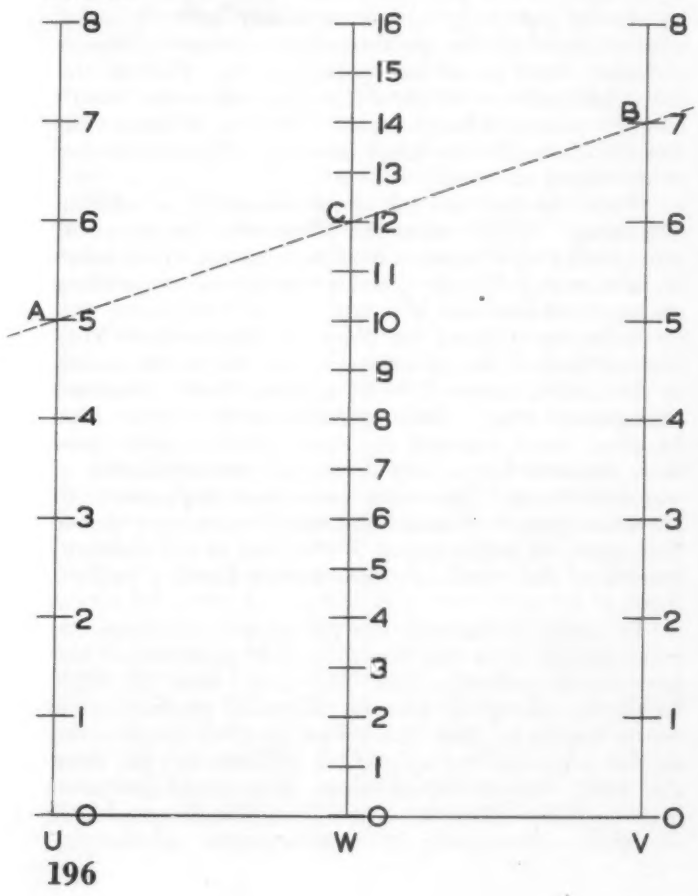
A simple case shows that this peculiar property can actually exist. Let the equation be $u+v=w$. Figure 1 consists of a horizontal line cut at U, V and W by three perpendiculars, two of which are equidistant from the third. Starting with zero at U and V, graduate the U and V lines uniformly and similarly in the standard unit but graduate the W line twice as closely. Let the dotted line create a trapezoidal figure $ACBVWU$. Then we know from grammar school that $CW=\frac{AU+BV}{2}$ or

$$2CW=AU+BV$$

But $AU=u$, $BV=v$, and $2CW=w$ by construction. Hence by substitution the graduations at A B and C obey the law $u+v=w$. Since ABC was a random line we have the proposition that colinear graduations on this chart always obey the law $u+v=w$.[2] Thus we have succeeded in creating an alignment chart for this equation in three variables and knowing values of two of them we can always find the value of the third by employing a straight edge.

The same simplicity of operation is very often applicable to charts drawn for much more difficult equations. The theory employed to produce a chart such as appears in Figure 2[3] is of a very much higher order than that for Figure 1 and the chart's contribution is of proportionately higher value. In this chart the central figure is a curve with a peculiar equation whose discontinous fragments had to be united in order that a useful diagram might result. In engineering practice the variables x and z are known and the resulting transcendental equation in the unknown y_0 requires great labor for its

Figure 1



[1]The terms "alignment" and "nomographic" are often used interchangeably. Actually the latter is a broader term embracing not only alignment charts but also any chart which presents an equation graphically. They have been used interchangeably in this article.

[2]This will hold true even though negative values are introduced.

[3]Reprinted from "Industrial and Engineering Chemistry," vol. 33, page 1082, August, 1941. "An Alignment Chart for Optimum Amount of Cooling Water in Heat Exchangers" by R. D. Douglass and D. P. Adams.

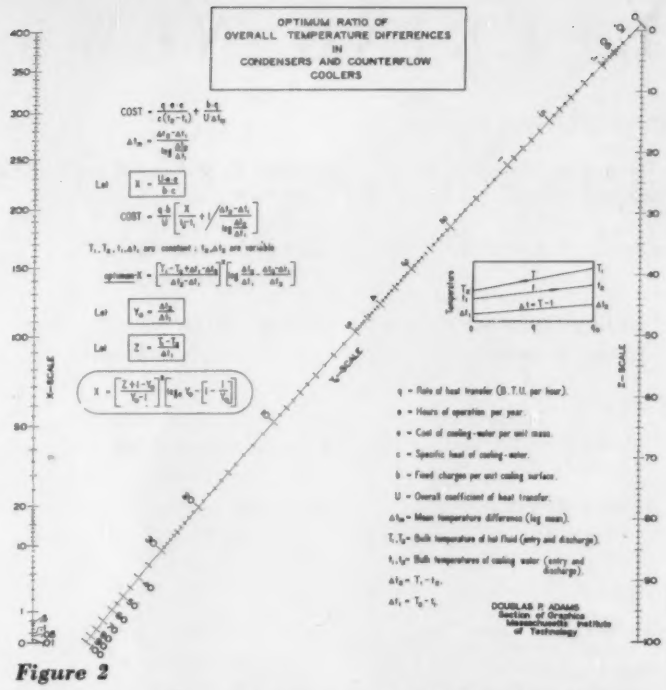


Figure 2

evaluation. Figure 3 does not over-dramatize the contribution of such a chart.

Certain characteristics of alignment charts are now apparent from these examples but should not be mistaken for limitations on the practicality of the method. Thus it is clear that the range of the variables of the chart is forever limited to those values set forth in the original chart but it is equally apparent that it was the physical characteristics of the engineering process which the chart was designed to serve which imposed these limitations. Had the physical set-up been different, the chart would have been adapted to meet it. This statement reflects the fact that the general aspect of a chart is frequently a very direct and forceful interpretation of the physical roles of the operators present in the equation. It is also true that three-figure accuracy is all that can consistently be expected from a good chart. The class of engineering operations, however, where three figure answers are either very helpful or entirely sufficient is so great as to insure extensive applicability of the method. The individual labor of designing and drafting a chart skillfully and accurately is frequently a substantial task but is quickly saved many times over by the chart's repeated use. This is often true even of charts for very simple equations in cases where the computations would otherwise be carried out by laborers or persons unfamiliar with the simplest arithmetic.

The rapid extension of the type of ingenuity employed in Figure 1 is immediate. Instead of plotting the scales uniformly we might plot them according to a logarithmic scheme whereby

$$UA=\log u;\ VB=\log v;\ 2WC=\log w$$

but since $UA+VB=2\,WC$
we have $\log u+\log v=\log w$, or

$$u\cdot v=w$$

Hence this diagram is an alignment chart for this equation. Further extensions of these methods to equations of the form

(1) $$k\cdot u+l\cdot v=m\cdot w+g$$

and (2) $$(u+p)^k+(v+q)^l=(w+r)^m+a$$

requires merely greater care in execution but need not be based on different theoretical considerations. The aspect of either chart will be that of three parallel scales, uniform in the first case and logarithmic in the second. The presence of the constants and exponents has the general effect of condensing the graduations, of shifting the scales up and down, or of shifting the inner one away from a central position. The accomplished nomographer must not only juggle these factors but meet the further demand that he cause his overall figure to fit into and entirely consume a certain available rectangular area. The very great number of engineering formulae which can be put in the above form cause this chart consisting of three parallel scales consuming a rectangle to be the best known of any single type.

A second kind of chart which takes care of the same equation (2) is shown in Figure 4. We observe an advantage of this type of chart in that the scales on the sides are uniform for the simple equation $u\cdot v=w$, permitting an easier compounding of it with other types.

The charts shown above all employ scales which lie along straight lines and require but one alignment. The more advanced theory quickly shows that a chart may contain three curved scales or even three sets of curved scales. Hence as many as six variables may theoretically be accommodated. An alignment chart employing two straight scales and a network or set of scales for the equations $x^3+ax^2+bx+c=0$ over the given range of variables appears in Figure 5.[1] The solution $x=1$, $x=2$, $x=12$ for the values $a=-15$, $b=38$, $c=-24$, is drawn upon the chart. Note that since a change in the sign of a root merely reverses the algebraic sign of a and c, it is sufficient to plot positive values of x.

Figure 3

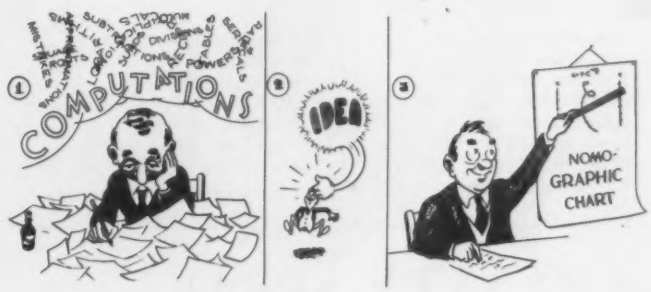
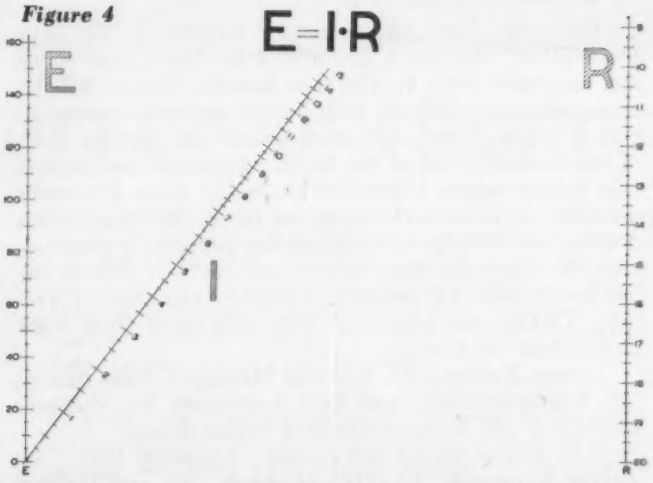


Figure 4



Alignment charts for more than three variables may frequently be compounded, by the ingenious use of auxiliary variables, from several charts each of which contains only three variables. Figure 6 shows a chart for the nine variables of equations (*Continued, page 206*)

[1] This method is particularly helpful for furnishing the first digits for Horner's method.

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FRANKLY SPEAKING . .

EXEUNT

With this issue the board of Volume XXII says goodbye to The Tech Engineering News and turns the magazine over to the new board. Theirs will be an increasingly difficult task as the present emergency makes unusual demands on the time and energy both of the students and of the faculty members and industrial leaders upon whom the magazine relies for many articles. It is at such times as these, however, when interest in scientific and engineering progress is greatest, that the magazine may be of most service. We of the old board wish all possible success to the staff of Volume XXIII, and hope that they will enjoy their work as much as we have.

James Harker, '43, General Manager; John Sibley, '43, Editor-in-Chief; and Jack Karstrom, '43, Business Manager, will compose the new Senior Board.

The Junior Board will consist of Stanley Felix, '44; Arthur Komarek, '44, Alan Michaels, '44, and William VanRavenswaay, '44, Associate Editors; David Jealous, '44, Publications Editor; Lee Eagleton, '44, Personnel Manager; Paul Heilman, '44, Publicity Manager; Bernard Dale, '43, Circulation Manager; Norman Greenman, '44, Associate Circulation Manager; Thomas Lawson, '44, Treasurer; and Frederick Lehman, '44, Advertising Manager.

Twenty-five men will form the Sophomore Board. Those in the editorial department are Corwin Brumley, '45, James Cooley, '45, John Colton, '45, George Curran, '45, Peter Davis, '45, Rafael Feuerring, '44, Robert Jevon, '44, Joe Lester, '45, Lyman Morgan, '45, Albert Shelby, '45, Roger Smith, '45, Clyde Snyder, '45, Robert Thirkield, '45, and Rowland Vance, '45. Those in the business department are Thomas Bell, '45, Alfred Bretschger, '45, Steffen Dieckmann, '45, Norman Everett, '45, Richard Gregg, '45, William Lockwood, '45, James McKelvey, '44, Hanns Maier, '45, Thornton Smith, '45, Richard Sweeney, '45, and Robert Sykes, '45.

THE SECOND DISCOVERY OF AMERICA

In America, science is discovering a vast new world—a stupendous world that Columbus never dreamed of. This new America is boundless. Its riches are infinite, thanks in large measure to the magic of *synthetic organic chemistry.*

One of the discoveries in this field is an amazing series of synthetic plastics—"Vinylite" resins.

In one form or another, these astounding materials appear in such diverse essentials as food-can linings . . . and tank-car linings; as airplane cockpit covers . . . and non-flammable insulation for vital electrical wiring; as corrosion-resistant wrappings for cross-continental pipe lines . . . and welders' goggles; as the thin film on paper which is put inside bottle caps . . . and as the invisible interlayer in the sandwich of safety glass.

"Vinylite" resins can be formed, drawn, laminated, and bonded. In basic form, they are odorless, tasteless and non-toxic, and range from non-flammable to slow-burning. They can be made stiff or flexible . . . hard or soft . . . colorless or almost any color under the sun . . . transparent, translucent, or opaque. And the result is resistant to oxidation . . . waterproof . . . alcohol-, alkali- and acid-resistant.

These unusual properties have created a heavy demand for "Vinylite" resins, particularly to meet defense needs. This is why it is not possible, at present, to supply all manufacturers of articles for personal and home use with all the "Vinylite" resins needed. Against the return of more normal times, when larger quantities for normal uses will again be available, manufacturers are invited to test these new plastics . . . to develop new and improved things to be made from them . . . so that all can benefit from the discovery of "Vinylite" resins.

• • •

"Vinylite" resins and plastics are supplemented by the well-known products of Bakelite Corporation. The resins themselves are produced by Carbide and Carbon Chemicals Corporation. Certain elastic sheetings and films are made from these resins and marketed by National Carbon Company, Inc., under the trade-mark "Krene," while other compounded forms useful in electrical insulation are marketed by Halowax Corporation. The manufacture of all these products has been greatly facilitated by the metallurgical experience of Electro Metallurgical Company and Haynes Stellite Company and by the metal-fabricating knowledge of the Linde Air Products Company. All of these companies are Units of Union Carbide and Carbon Corporation.

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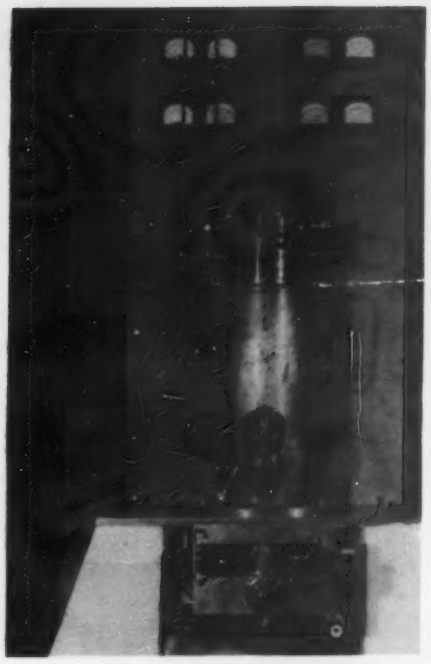


Figure 3
(b) Close-up view of bottom sections showing viewing ports, camera, and lens current knobs

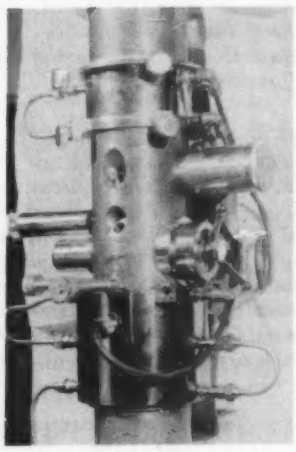
10,000X

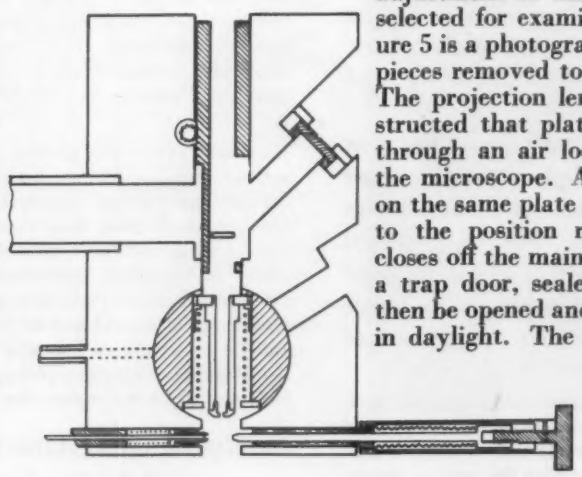
(*Continued from page 194*)

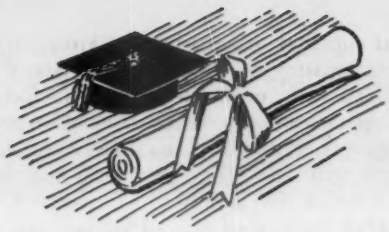
in angstrom units is given by $\lambda = 12.2/\sqrt{V}$ provided that V is not greater than about 100,000 volts so that relativity effects may be neglected. For example, an electron which has been accelerated through 40,000 volts has a wavelength of 0.06 *A*, or roughly 100,000 times shorter than visible light. On the other hand, the numerical aperture of most electron microscope objectives is somewhere around 0.01 to 0.02 or, roughly, 100 times smaller than for the optical microscope. The net result is a gain of a factor of about 1000 in the theoretical resolving power of the electron microscope over that of the optical microscope. That is, if diffraction were the limiting factor, we should actually be able to photograph in detail objects about 1000 times smaller by using an electron microscope. With present design electron lenses, however, it turns out that spherical aberration is an important limiting factor. It may be shown that for the range of voltages usually employed (50–90 kv) the limitation due to spherical aberration is of the order of a few hundred wavelengths and around 20 to 30 *A* is about the best that has been attained. This still represents a gain of about 20 times over the best optical microscope. Another limiting factor is the constancy of the electron energy and the lens currents. It will be recalled that the focal length of the lens depends on V, which is a measure of the electron energy. If this is not absolutely constant then the focal length will vary, thus smearing out the image. This can be caused either by fluctuations in the accelerating potential or by loss of energy in any way, such as by scattering in the object support. In order to realize a resolution of 10 *A* it is necessary to keep the accelerating voltage and the lens currents constant to a few thousandths of a per cent. This is done by means of electronic stabilizing circuits.

There is shown in Figure 3 a photograph of the instrument which has been constructed in the Physics Department here at the Institute. The microscope itself is in the center. The cabinets beside the microscope contain the power supplies and current and voltage regulators for the lens currents on the left, and on the right the main switchboard and the high voltage regulator. The accelerating voltage is obtained from a high voltage transformer with full wave rectification and a 0.3 microfarad condenser for smoothing, in an adjoining room. This supplies voltages up to 100 kv. The output of this is tied to the high voltage stabilizer which in turn controls the input voltage across the transformer in such a way that line voltage fluctuations of as much as 10 per cent would cause a change of only a few volts in the output. However, the line voltage is first stabilized to a fraction of a per cent by means of a saturation core transformer. A 700-henry choke in the d.c. output effectively reduces the a.c. ripple caused by the load to about half a milliampere. This very constant voltage is brought to the cathode of the microscope on a line designed to reduce corona loss as much as possible. Batteries for heating the filament and providing bias voltage are enclosed in a smooth metal box, visible behind the high voltage terminal at the top of the microscope. These are controlled through insulated leads to the main microscope panel. All other parts of the microscope are at ground potential. Below the high voltage terminal, in order, come the high voltage insulator, anode section, condenser lens, object stage, objective lens, intermediate section with observation window for viewing the first image, projection lens, final stage and observation window and, at the bottom, the camera. Figure 4 shows a photograph of the object stage, together with a cross-sectional drawing. The sample, mounted on a small disk of wire gauze, is placed in the end of the cartridge-like object holder. This is introduced into the object state through an air lock, the operation of which will be apparent from the drawing. Appropriate controls provide vertical and transverse adjustment so that any portion of the object may be selected for examination and brought into focus. Figure 5 is a photograph of the objective lens with the pole pieces removed to show the construction more clearly. The projection lens is similar. The camera is so constructed that plates may be introduced and removed through an air lock without breaking the vacuum in the microscope. A number of exposures may be taken on the same plate and when the plate holder is brought to the position ready for removal it automatically closes off the main body of the microscope by means of a trap door, sealed with a gasket. The camera may then be opened and the light-tight plate holder removed in daylight. The reverse procedure is followed in reloading, the camera being first evacuated by means of an auxiliary pump before the trap door can be opened. (*Continued on page 204*)

Figure 4
(a) Object stage in place with condenser lens coil above and objective below
(b) Cross-section







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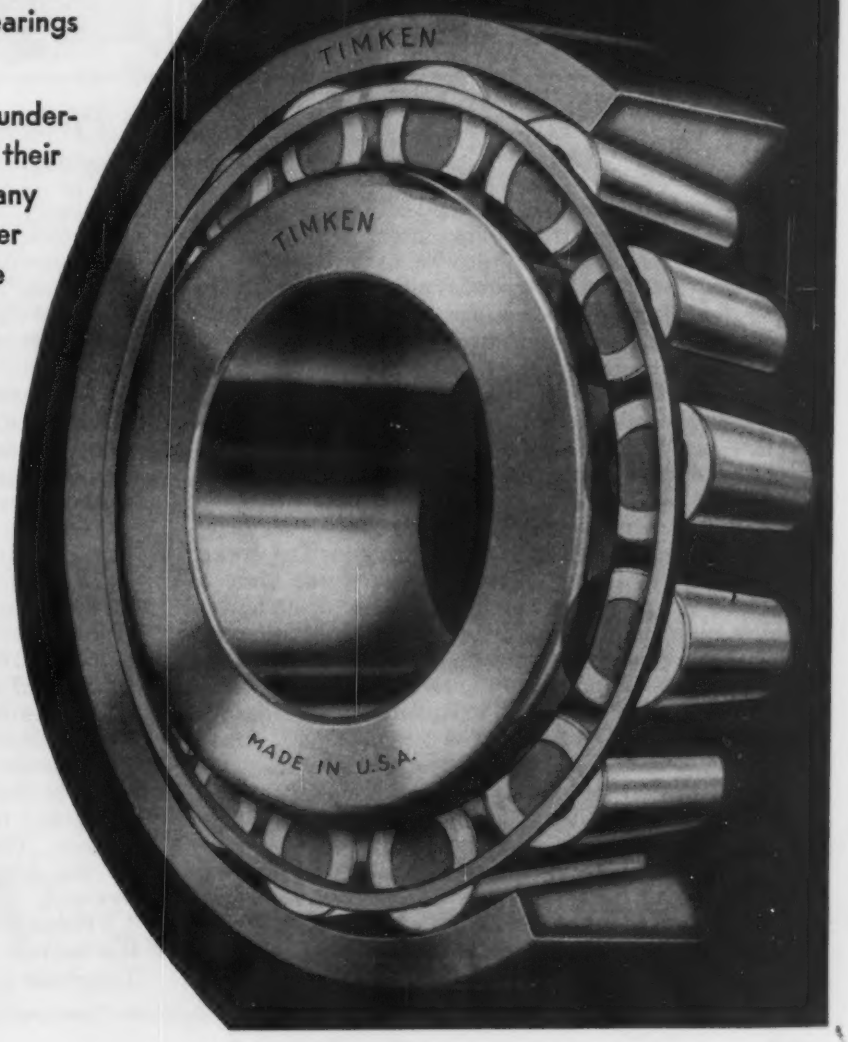

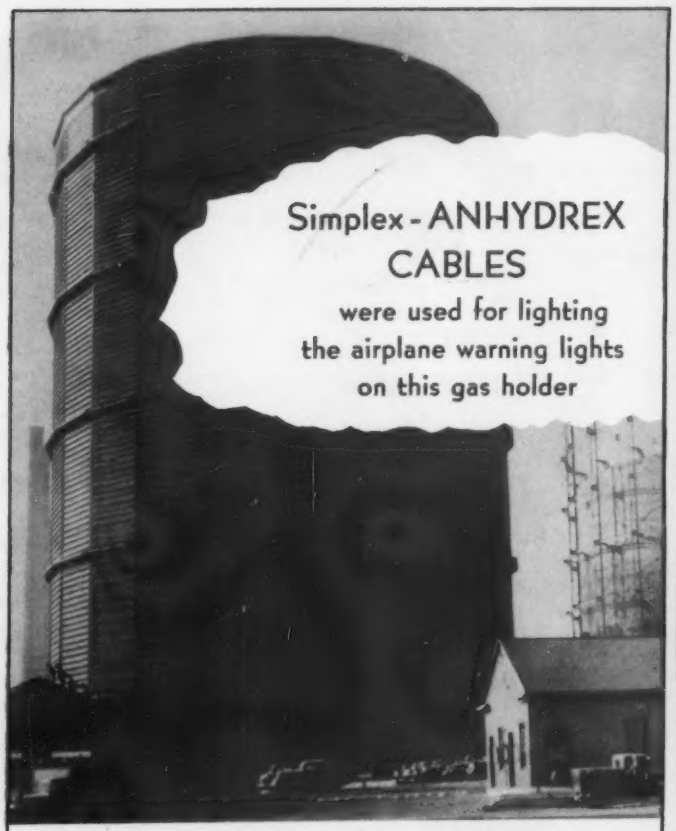

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EXIT: *"Number Please!"*

(*Continued from page 192*)

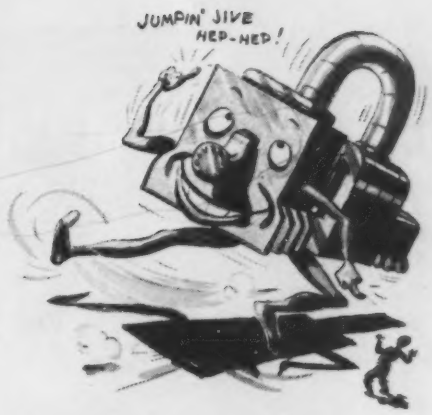
The verification for the installed equipment occupies about ten weeks of the installing interval. Verification is merely a name given to a process of determining the service performance of central office equipment by physical or electrical inspections. In some frames, such as the test frames, every piece of equipment is inspected. In the larger frames, where there is a great deal of the same sort of equipment, a sampling procedure is used. To guide the installer in this type of work, the Bell System provides an installer's handbook, which describes in detail the plan to be followed in the sampling procedure. Incidentally, other handbooks are available to the installer to keep him posted on the newest developments which deal with his particular job. The worker inspects the equipment in sample lots, the sizes of which are set up in the handbook tables. If he finds a smaller number of adjustment irregularities than the AN (a certain portion of a sample), it is indicated that the rest of the equipment in the sample is in good working condition. If his list of irregularities exceeds AN, the sample lot must be inspected completely. A certain sample may have a number of irregularities less than the AN but still that number will exceed the SN (spottiness number). This number applies to a concentration of irregularities within a subgroup and an exceedingly large number of irregularities will mean that all the equipment will have to be verified. When inspecting relays, a small gauge is inserted near the armature which will insure minimum armature motion and thereby set up adverse working conditions. Thus if the equipment functions properly under these conditions, it will invariably work under normal operating conditions. Complete records of these verifications are kept and sent back to the Bell Laboratories whose technicians analyze them and change any manufacturing requirements that they deem necessary in order to produce more perfect equipment.

The testing of equipment is done in a period of sixteen weeks during the installing period. Testing operations are performed with test equipment which puts the central office equipment through its regular operating paces and then checks its action. After the cutover, the equipment is always under continual test. Any difficulties show up at a maintenance center.

In cases of damage to certain pieces of equipment, duplicate paths are established almost immediately. A large part of the central office equipment is designed to operate on forty-eight volt storage battery current. A commercial power line is used to furnish building lighting and through proper conversion is used to charge the storage batteries. The dial tone, busy tone, and ringing machine are also operated from the commercial power lines. In the event of failure of commercial power lines, emergency machines can be operated from the storage battery. This is one example of the precautions taken by the telephone company to insure uninterrupted service.

The scheduled turnover of the installation job by the Western Electric Company, Inc., to the Illinois Bell Telephone Company is set (*Continued on page 204*)

Once there was a jitterbug that weighed 800 tons!



How Westinghouse Engineers Made Vibrating Turbine Generators Calm Down

WHEN the two-pole turbine generator came along, it was hailed as a great thing. And it was. It delivered enormous amounts of amps and volts, did a titanic electrical job. But . . .

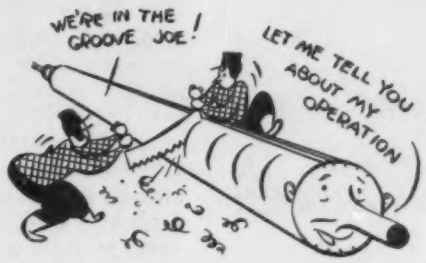
Its rotor vibrated and endangered the alignment of the bearings, collector rings, and brushes. Its stator vibrated and made the foundations tremble. And, to make bad things worse, the vibrations were different from those found in the four-pole 1800-rpm machines—and they couldn't be eliminated by the usual balancing methods. Engineers had a tough problem on their hands.

► Westinghouse engineers studied the rotor and found that it was acting like a two-by-four piece of wood. A two-by-four sags more lying flat than lying on its edge. It was the same with the long, slender, two-pole rotor. It sagged more lying one way than another.

This was why: Along two sides of the rotor, deep lengthwise slots were cut for the field windings. Naturally, the rotor had more give on the slotted sides than the solid sides. So, as the rotor turned, the give in the slotted sides made the downward force on the rotor supports change twice each revolution. The result: the rotor made the machine vibrate 120 cycles a second.

► What to do?

Dummy slots in the solid sections of the rotor would have equalized its rigidity. But Westinghouse engineers did something better. They cut several grooves across the solid sections. These grooves made the rotor's rigidity equal on all sides, *without disturbing the magnetic flux*. The turbine generator worked at top efficiency, the vibration at the supports was reduced 88%, the rings, brushes, and collector rings didn't take such a shaking-up.



► That took care of the rotor. But Westinghouse engineers also had to figure out what to do about the stator vibration.

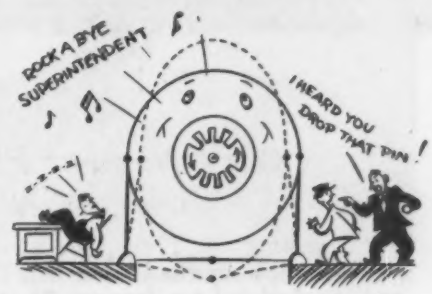
Massive as it is, the stator was being pulled out of shape, first on top and bottom, then on the two sides. The 400,000-pound magnetic force of the two-pole rotor was doing the pulling as it turned.

► Of course, the change in the stator's shape was too minute to be seen. But it could certainly be heard. For this change in shape was transmitted to the stator foundation as a 120 cycle vibration. From the foundation this vibration travels to floor and walls, making them hum.

To put a stop to it, Westinghouse engineers developed a special, flexible mounting for the stator. It is as though the stator were supported on two sets of links. One set goes along with the stator when it vibrates horizontally, but doesn't budge when the stator vibrates vertically. The other set goes along with vertical but not with horizontal vibrations.

► The effect of this ingenious arrangemen is that there is no motion at all where the links are attached to the stator foundation! The vibration at the supports is reduced by 75%, the noise lowered to less than ordinary power station noise levels!

The job was done. Stator vibration was absorbed. Rotor vibration was calmed down. Westinghouse engineers had 3600-rpm, two-pole turbine generators pouring out great electric power, and making no more vibration than machines running at half their speed.



► The electrical industry was through with that vibration trouble for good.

★ ★ ★

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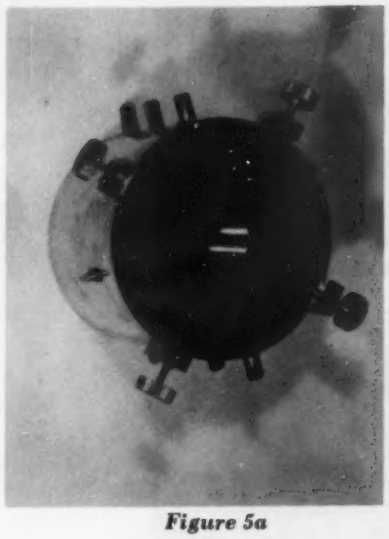


Figure 5a

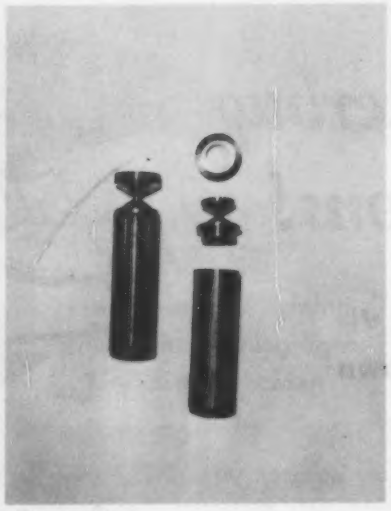
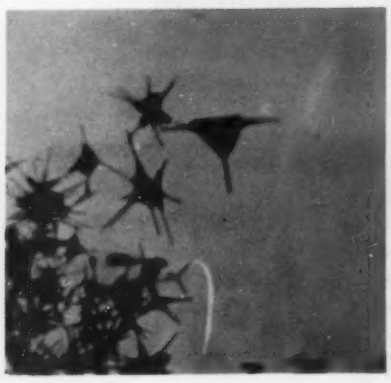


Figure 5b



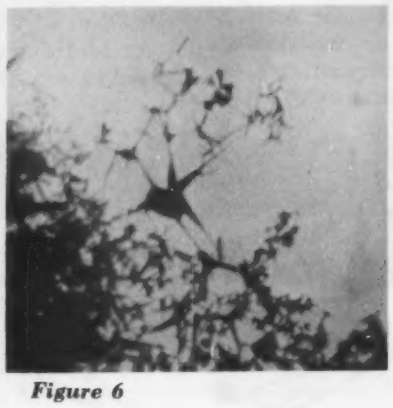


Figure 6

EXIT: *"Number Please!"*

(*Continued from page 202*)

for December 20, 1941. The actual cutover to dial service is done by the Illinois Bell Telephone Company and is scheduled for January 31, 1942. The public is informed of this changeover in a number of ways. An insert in the monthly telephone bill is the first notice. Later a letter precedes the telephone company installer's visit to each customer's premises, at which time he places a dial on the telephone instrument. Another insert covering proper dialing technique will be mailed to the customers preceding a personal demonstration by one of the members of the instructions squadron of the Illinois Bell Telephone Company. In addition to this, a sound movie short illustrating correct dialing technique will be shown at several theaters located in the new dial area.

Since it is necessary to maintain telephone service while the new exchange is being built, the old equipment has to be kept in good condition. Following the changeover, the old equipment is taken out by the installation crew. In the case of the Rogers Park Exchange, this available floor space will be used for future expansion and office space. A group of engineers from the Illinois Bell Telephone Company stays on duty at the exchange after the cutover to assist in any technical problems that might arise.

After these new central office units are cut over about forty-three per cent of the Chicago telephones will be dial operated.

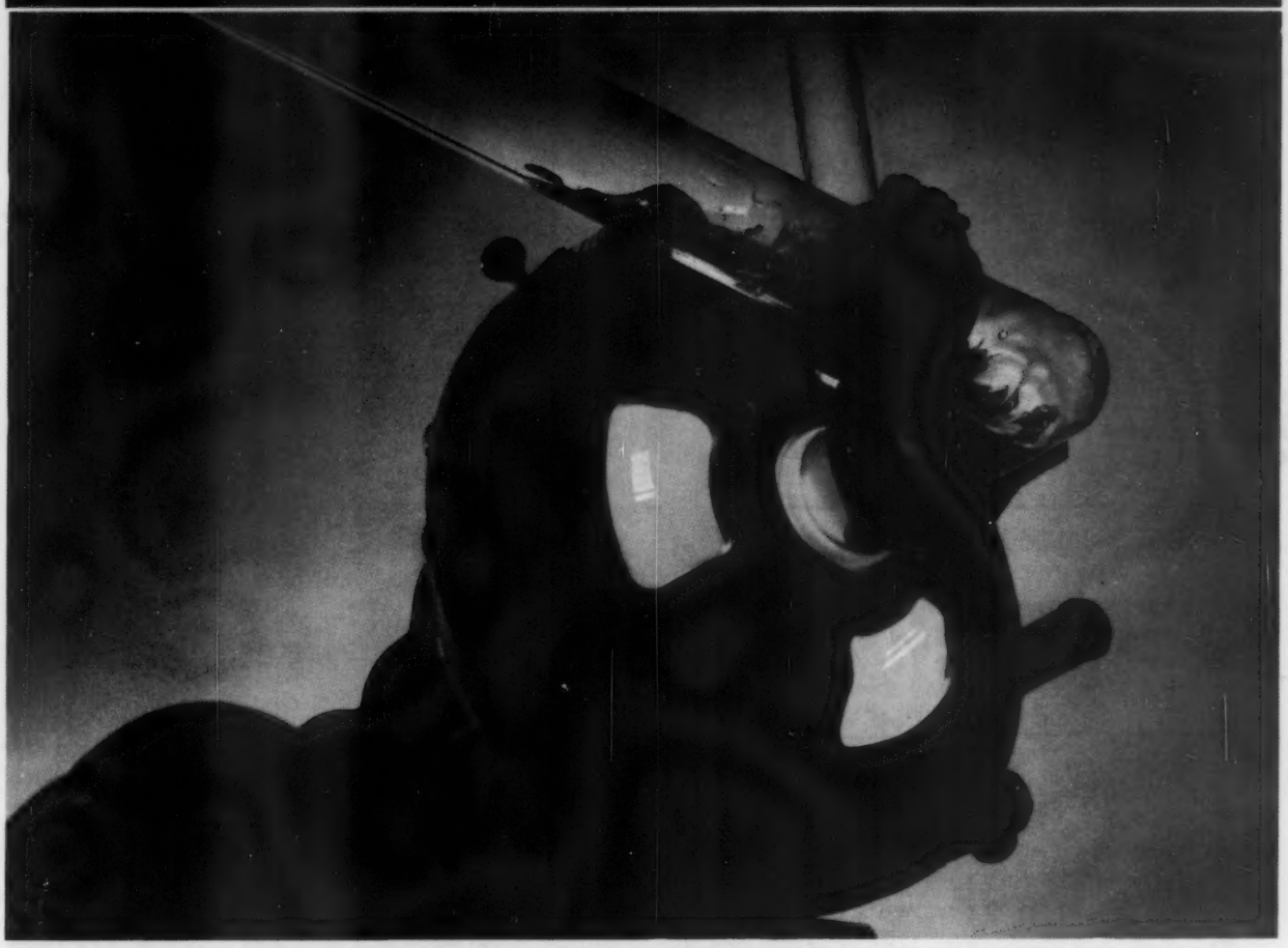
10,000X

(*Continued from page 200*)

Since electrons will penetrate only a very small thickness of matter the objects to be examined must be supported in a special way. For example, if we wished to investigate the size and shape of small particles, we might suspend these particles in a dilute solution of collodion and then form a thin film (100 to 200 *A* thick) on water and mount this film on one of the wire gauze disks. Other methods adapted to the nature of the material to be examined will suggest themselves. In operation, the specimen, mounted in one of the object holders, is inserted in the microscope. Assuming the microscope to be aligned, the condenser lens current is adjusted until the electron beam is properly focussed, as observed on a small fluorescent screen (near the top of the object stage) which can be inserted in the beam or removed at will. The position of the object and the object lens current are then adjusted until an image of suitable magnification is in focus on the intermediate fluorescent screen. This magnification is usually around 100 to 200; that is, small enough so that a general view of an appreciable area of the sample can be seen. A portion of this image is then selected for further magnification and the object moved so that this portion is brought over a small hole in the intermediate screen, thus allowing the beam to pass through to the projection lens. The projection lens current is then adjusted so as to produce the final magnification desired and the image focussed on the bottom fluorescent screen. Several fine adjustments are provided for the various lens currents and after these have all been adjusted so that the final image is in the best focus the bottom screen is swung out of the way and the image allowed to strike a photographic plate in the camera just beneath. An average exposure time is of the order of half a minute. Since the magnification in each stage is from 100 to 200 the final magnification may be 10,000 or more. In Figure 6 there are shown some pictures of zinc oxide crystals of a magnification of about 12,000. The specimens were prepared by letting some smoke from a zinc arc in air deposit on a piece of fine copper gauze held above the arc. The fine needle-like formations are a few hundred angstroms in width.

It will be at once evident that the electron microscope is not an instrument to replace the ordinary optical microscope, but rather to supplement it. The electron microscope is an instrument of extreme resolving power, but the types of specimens that may be examined are rather restricted. The necessity of placing the sample in a vacuum is a serious limitation. Also, it must be remembered that what the electron microscope sees is the variation in penetration of the electron beam through the specimen, or roughly, the surface density of material in the path of the beam. On the other hand, for such problems as the determination of particle size and shape the electron microscope extends the region of direct measurement by one or two orders of magnitude. This is a tremendous step. In the biological field, bacteria of such a size as to be barely distinguishable from points by optical methods, may be examined in detail as to size, shape, and sometimes internal structure. Some work has been done on the surface structure of metals by applying a thin film which is peeled off and examined; this method, while indirect, seems to offer considerable promise. Wherever extremely high resolution is required and the material may be prepared in suitable form, the electron microscope offers a solution to the problem — but its limitations and its advantages should both be kept in mind.

Here's the Glass pump that couldn't be built . . .



THE ENGINEER from the Chemical Works had one of his usual headaches.

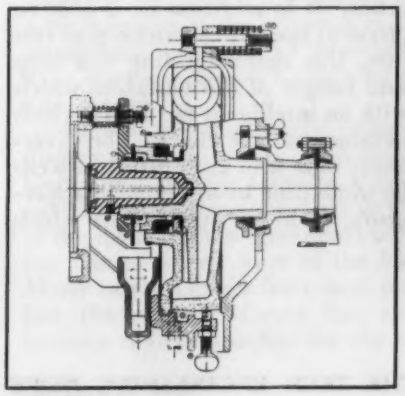
"We're pumping hot corrosive acids through your glass pipe, and it lasts for years," he moaned, "and the works bogs down because the pumps can't take it! Can't you people build a glass pump?"

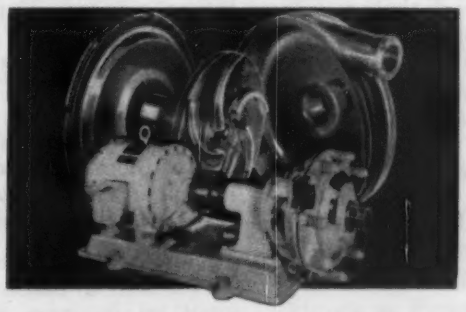
It sounded impossible. Pump makers said it couldn't be done. Such a pump required not only highly resistant glass but also intricate parts, accurate to thousandths of an inch! Even Corning had doubts but decided to tackle the problem.

Pooling its ideas with Nash Engineering Company's knowledge of pumps, Corning devised new methods of glass manufacture, even a new type of glass for certain parts.

And today chemical, food and beverage plants, and other industries handling corrosive solutions have a glass pump that works like a charm. Resistant to corrosion, it eliminates a cause of product contamination and undesirable chemical reactions. Resistant to heat shock, it may be cleaned with hot acids. Transparent, it permits constant visual inspection for cleanliness, color, sedimentation.

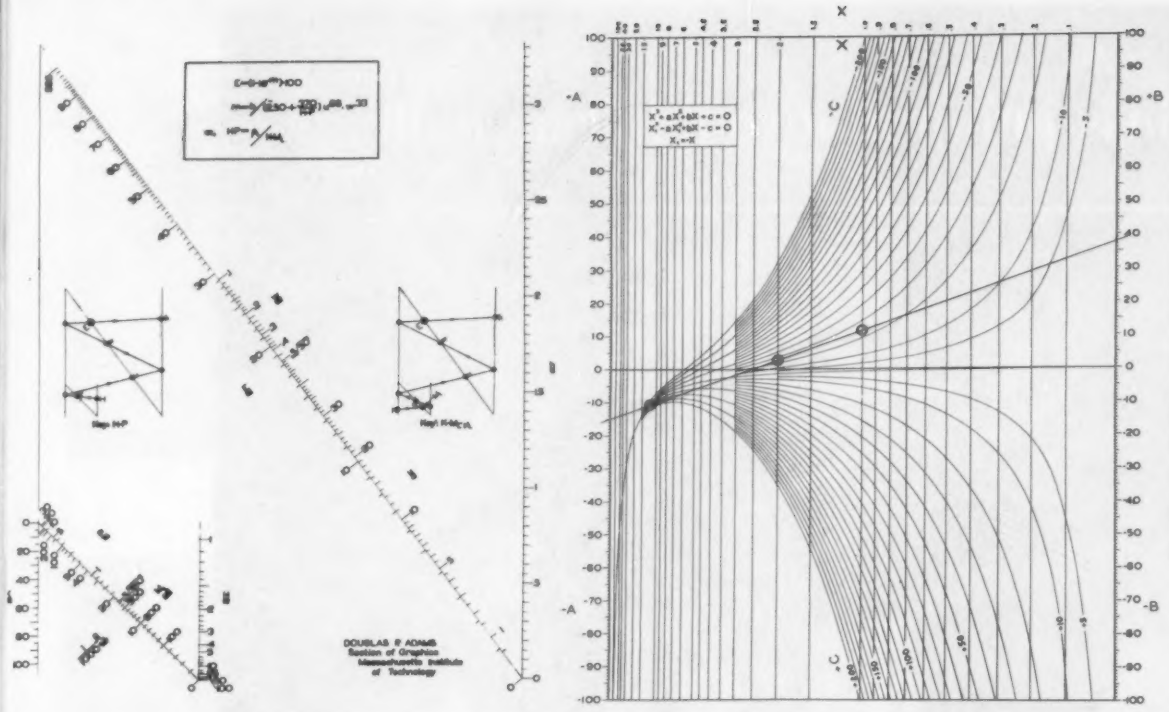
In the same way, Corning research for three quarters of a century has licked such glass problems as the bulb for Edison's first lamp, cooking ware for housewives, and tiny glass springs for chemical equipment. And in these days of metal-conservation, Corning ability has reached a new high in usefulness as engineers and production men use glass to solve their new problems. Industrial Division, Corning Glass Works, Corning, N.Y.





The Nash Glass Centrifugal Pump (left — cross section; above —coupled with driving motor, glass pump parts in background) can handle up to 6000 gal. of corrosive acids and chemical fluids per hour against a 65-ft. head.

CORNING
means
Research in Glass



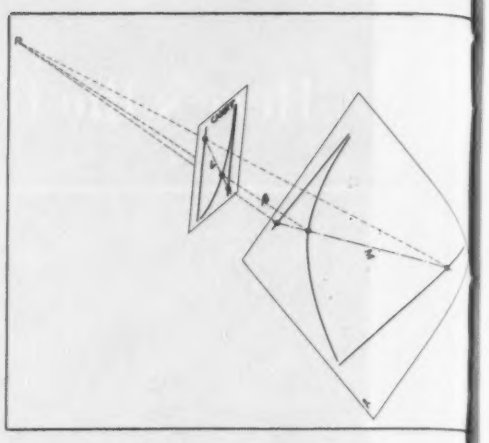


Figure 5. (*Left*)
Figure 6. (*Center*)
Figure 7. (*Above*)

TIME IS VICTORY

(*Continued from page 197*)

$$E=(1-10^{-m})\cdot 100 \tag{3}$$

$$m=\frac{h}{\left(2.50+\frac{.370}{H\cdot P}\right)\mu^{.68}\omega^{.33}} \tag{4}$$

$$H\cdot P=\frac{\rho_L}{KM_L} \tag{5}$$

Here the nomographer was requested to make a chart which could be entered with values of H and P in equation (4) or with values of ρ_L, M_L, and K of equation (5).

The scope and power of the subject of nomography are due basically to a single fascinating property. Let us place any alignment chart in a fixed position in space (Figure 7) and project it from an outside point P onto a new plane α not containing P and not parallel to the plane of the chart. The projection from P onto plane α of a point of the original chart will be given by the intersection with plane α of a line through P and through the point. Let all the essential details of the original chart be so projected onto plane α. *The resulting configuration on plane α is an alignment chart for the same equation.* This is apparent from the observation that if three graduations were colinear on the chart in line L, then the projection rays through these points and P are coplanar with L and P in a plane β. Plane β contains the projections onto plane α of the three graduations and these projections are colinear in the line M of intersection of plane α with plane β. The original rectangular outline of the chart will in general be projected into an irregular quadrilateral upon plane α and it seems possible that if the roles of the first and second charts are reversed we shall be able to take a chart which consumes an irregular quadrilateral and carry it over by such a central projection in space into a new chart consuming a rectangle of specified dimensions This projection can actually be accomplished and allows us to draw up a chart in any form, bound the portion we wish to use by an irregular quadrilateral, and then project this figure into a new one consuming a specified rectangular space. It is also possible through such projections to manipulate the shapes of the scales, the densities of their graduations and, to some degree, the points on scales which shall be inaccessibly far away. The advanced approach to these operations is through the tools of projective geometry and under such a basic treatment the entire subject of nomography quickly assumes a fluid aspect, but it should be emphasized that elementary principles can be the backbone of its development.

The practical engineer does not regard nomography as an academic exercise but requires the immediate drafting of his chart as soon as its design has been skillfully worked out. The layout should be made as large as conveniently possible and permanence should be sought through inking. Since a line of colineation might cut a scale at a low enough angle to create an error which could subsequently be magnified, it is valuable to strive for the highest drafting accuracy. Hence the nomographer seeks as great proficiency in his drafting as in his mathematics. If in addition he is able to grasp the gist of the physical operations which give rise to the original equation, this understanding will help him treat the limits and ranges of the variables which have been given him with an intelligent flexibility which greatly adds to the usefulness of the chart. The diversity of these requirements cuts into the output of well-made charts and at the same time brings greater appreciation in the engineering world for every chart which does its job well.

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GEMS — AND BORT

(*Continued from page 195*)

that many diamonds mined in 1928. Fewer diamonds are being mined this year since the war has interfered with production in the South African mines which are owned by Britishers and from which the major portion of the diamonds come today.

Many tons of rock must be moved to yield a single diamond. From 350 tons of rock and gravel a good mine may yield 46 carats of rough diamonds. All of this will be classed as commercial diamonds except about 23 carats. When the stones of poor color and those badly flawed are removed, about 12 carats of good diamonds will remain. Next the small stones are taken out and a two-carat diamond may be left. In the process of cutting, a fine one-carat diamond likely will emerge.

A development in the diamond industry arising from the war, which will affect the pocketbook of many a bridegroom, is the advance in the price of melee, the small diamonds such as those set into wedding bands. This price rise did not happen by chance but has a definite reason.

Before the war began, almost all of the smaller diamonds were cut in Amsterdam, Antwerp and in Germany. Entire families were engaged in diamond cutting, often doing the work in their homes. The story of the flight of these diamond cutters before the advancing armies is now part of the history of the invasion. Many of the cutters have now returned to their homes but the melee industry has not regained its place because it is impossible for the cutters to import diamonds. Various plans have been made to transplant the melee industry to this country but so far high wages have thrown up a barrier.

The melee industry must not be confused with the cutting of large diamonds which is now being carried on successfully both in the United States and in South Africa.

For gem purposes the diamond has held first place through the centuries not only because of its extreme degree of hardness but because the index of refraction of a diamond is the highest of that of any stone. The prismatic rainbow colors in the sparkle of a well-cut diamond exist because of all gems the diamond has the greatest dispersion of light. Brilliance is enhanced by scientific cutting. Neither a stone cut too thick nor too shallow will give the true brilliance which determines the value of a diamond and is the quality most to be desired.

A thick stone is heavy and can be sold at a low price per carat; one that is shallow will show a wide surface but little brilliance. These dull stones known as "fish eyes" frequently turn up through alleged distress ads in the classified columns of newspapers. Such diamonds are not worth the money asked. It is always best to buy a diamond from a reputable dealer who will tell the truth about the stone.

Fluorescence is a peculiar quality occurring in some diamonds, which is still puzzling. These diamonds are known as Premiers from the fact that they first came from the Premier mine. Under sunlight these are a

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very beautiful blue but in artificial or transmitted light much of this color and beauty are lost.

It was a Belgian lapidist, Ludwig van Berquem, who discovered in 1475 that the diamond could be cut with its own dust. This opened the gateway to new beauty. Since then cutting of the diamond has gone through many phases up to the present 58-facet cut, universally accepted as the cutting giving the greatest brilliance. In a properly proportioned and polished diamond the light is reflected from the back facets. Color within the diamond arises from amounts of impurity in the carbon.

By accident and luck, some diamonds of great value have been found and picked up by Boer farmers, children and African natives, but this is the exception; most diamonds are produced by hard work.

Diamond mining goes back to India, originating in the years between 600 and 800 B.C. It is believed that for about 1200 years all diamonds came from India. Then, about 600 A.D. diamonds were discovered in Borneo. The scene of diamond discoveries moved to Brazil in the eighteenth century. Today, the Brazilian supply is not great although it was in that South American country that the Vargas diamond, now being cleaved, recently was found. For the last seventy years South Africa has produced most of the diamonds in the world.

Of intense interest to geologists and mineralogists was the search for the origin of the diamond, which chemically is a crystalline carbon formed by gigantic heat and pressure.

Early finds were in river beds and in dry washes. How they came to be there, nobody knew. So many diamonds were found after rains that superstition pointed to the rains as diamond-bearing. The first scientific explanation occurred with the discovery of diamonds in South Africa. Only in South Africa and in the State of Arkansas, U. S. A., does the diamond appear in its original matrix or "blue ground."

From a study of this formation came the belief that ages ago in masses of molten rock existing in the depths of the earth minute particles of carbon began to crystallize as diamonds through heat and pressure. With the passing of ages, it is thought this molten rock pushed toward the surface bearing diamonds. Streams eating into this rock bore the diamonds downriver with lesser gravel.

Single diamonds have been found in Arkansas and in a number of our States situated in glacial regions but most of these diamonds are small and the mining industry in this country has never reached world importance.

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How can a throat microphone help win battles?

This throat microphone is something new—made by Western Electric for the nation's air forces.

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G-E Campus News

STEP ON THE GAS!

STEPPING on the gas to produce a speed increase of six feet per day along a highway wouldn't break any speed laws. But six feet extra per day makes engineers hang on their hats when the traveling is through solid rock. And that's the added progress being made by the company excavating the eastern portal of the new 13-mile Continental Divide tunnel by the installation of a new ventilating system utilizing G-E motors and control.

The system saves 20 minutes in the time between shooting each blast in the tunnel and getting back to drilling again. Fans spaced along the tunnel start up immediately after the blast, suck out the gas and smoke, and then reverse and blow fresh air into the tunnel. The fans start in sequence, with an interval of 20 seconds between each, so as to prevent building up large differences of pressure.

The tunnel is being excavated by the S. S. Magoffin Company, under the direction of the U. S. Bureau of Reclamation, to bring water for irrigation and power from Grand Lake, on the western slope of the Continental Divide, to the eastern slope.

CREEPY BUSINESS

STEEL, or any other solid material for that matter, deforms and creeps when subjected to heat and tress. But how much a given piece of steel in, say, a team turbine, is going to creep during its life of 10 or 20 years is something a designing engineer can't wait 10 or 20 years to find out.

That's why all sorts of accelerated creep tests have been tried—ways to get a hurry-up prediction of the behavior of metal in service. Dr. Saul Dushman (U. of Toronto '04), assistant director of the G-E Research Laboratory, has thrown some new light on this problem by devising a method that produces extensions in length of as much as half a per cent an hour. By it he can get information in a day or two that would have required months by older methods.

The method consists of loading a thin wire of the metal with a weight, heating it with an electric current to a bright red heat in an atmosphere of nitrogen, and measuring the extension. The results seem also to suggest that creep does not occur atom by atom along the length, but rather in the movement of groups of atoms numbering from 50 to 1000.

95% PERFECT

MILADY will find her reflected charms brighter if her mirror is coated with silver, but that reflection will wear better if the coating is aluminum. That's what Frank Benford (U. of Michigan '10) and W. A. Ruggles, of the G-E Research Laboratory, found when they tested 37 kinds of mirror surfaces.

Silver evaporated onto the front surface of the mirror from an electric filament reflected 95 per cent of the incident light. The initial score for aluminum was only 88 per cent. But six months later the aluminum mirror was just as good as ever, while the silver one had deteriorated considerably.

Gold, incidentally, scored third among the pure metals, reflecting 82 per cent of the light. But while all the other metals gave their best results when evaporated on the front surface of the mirror, gold worked best when deposited on the back, as is the practice with ordinary looking glasses.

GENERAL ELECTRIC

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